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(54) Method for determining the values of the electromagnetic field generated by a radio base station in an urban environment

(57) The method for determining the values of an electromagnetic field generated by a radio base station in an urban environment uses ray-tracer algorithms to calculate the optical paths and the visibility relationships between the various objects in the environment. Graphic techniques are used to speed up calculations by reducing the depth of the visibility tree between the transmitter and receiver, and simplifying the visibility test in the determination of the optical paths.

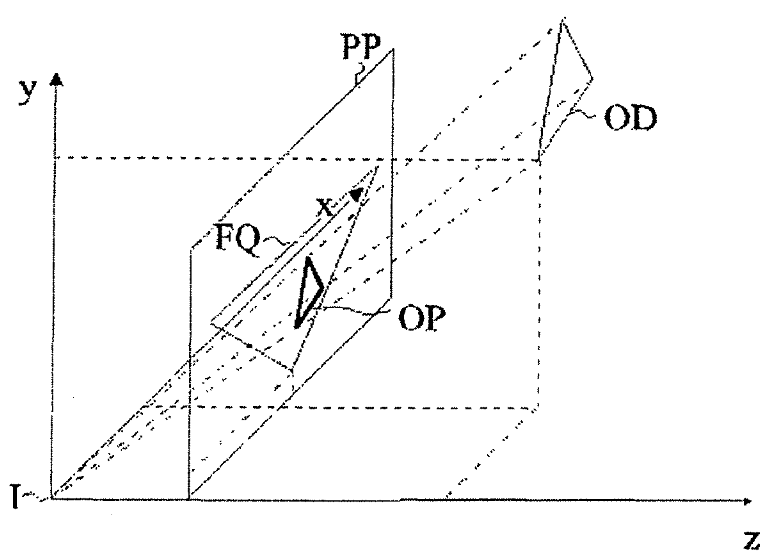

Fig. 4

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Description

[0001] This invention refers to the means for planning telecommunication systems on radio carriers, and in particular refers to a method for determining the values of an electromagnetic field generated by a radio base station in an urban environment.

[0002] The precise evaluation of electromagnetic field levels near radio base stations in order to check that legal restrictions have been observed, is today one of the fundamental aspects in the designing of mobile radio networks. Since the on-site measurement of electromagnetic field levels is often prohibitive cost-wise, and furthermore is not very selective when determining irradiating contributions, software instruments are becoming ever more frequently used to estimate the field levels.

[0003] Unfortunately the complexity of urban environments makes it difficult to solve the problem with theoretical calculations based on Maxwell's equations.

[0004] For this reason, and due also to the approximate description of the buildings of the environment under examination, methods have been used that estimate the electromagnetic field as the sum of contributions of reflected and diffracted rays that propagate in a straight line from the source.

[0005] An electromagnetic field evaluation application, as for example that described in "The Mobile Radio Propagation Channel" 2nd edition, by J. D. Parsone, Ed. John Wiley & Sons LTD, generally works in the following way: starting from a data base containing a vector map of the building and a data base of the irradiating sources, it calculates the optical paths of the signal that reaches a generic area of the urban environment. Subsequently, the optical paths calculated with the numerical calculation models can be used to find the values of the electromagnetic field, which can then be used to estimate the environmental impact that is a fundamental element in the design of a cellular network.

[0006] In the urban environment, the calculation of the optical paths is the most time-consuming part of the application. The complexity of the algorithm, in fact, is such that even the analysis of small areas of a few hundred metres takes far too long using present-day calculation instruments, unless optimisation procedures are used. For this reason, various techniques have been developed to introduce approximations that make it possible to perform this type of calculation in a reasonable amount of time. These techniques can be subdivided into two different categories:

- forward ray-tracer algorithms;
- backward ray-tracer algorithms.

[0007] In forward ray-tracer algorithms, a finite number of rays that are isotropically irradiated from the transmitter and their propagation into space is considered, taking into consideration possible reflections and diffractions with elements in the environment. To establish whether a ray reaches the receiver, the receiver is taken to be located at the centre of a sphere constituting the capture volume, and it is determined whether the ray intersects the sphere. This type of algorithm is suitable for studying propagation in a two-dimensional environment, whereas it is not very efficient when studying a three-dimensional environment. This is due to the considerable number of rays that must be irradiated isotropically into the solid angle, regardless of the direction in which there are objects that can interact. An operation that involves a great number of unnecessary calculations.

[0008] On the other hand, the backward ray-tracer algorithms calculate which rays connect a transmission source with a reception point, taking into account that they may, during their path, be reflected and diffracted a considerable number of times.

[0009] The most critical aspect of a ray-tracer algorithm, from the point of view of calculation time, is the "visibility test" performed between source and receiver, i.e. the check that there are no obstacles between the source and the receiver that may interrupt the rays. To perform this test, the most efficient algorithms are arranged to carry out two main operations:

- generate a structure, called "visibility tree", in which the visibility relationships between the various objects under examination, are stored;
- calculate optical paths.

[0010] The first operation builds up the visibility relationships between the various objects in the urban environment under examination. In practice, it defines the objects that can be reached by a ray that is reflected or diffracted by another object. The building of the visibility tree involves the problem of generating two-dimensional (2-D) images of three-dimensional (3-D) environments, which is called "image synthesis", and is performed by electronic processors. In actual fact, these techniques are very refined and only the parts required for the visibility test need be extrapolated for the propagation models, as will be explained later.

[0011] The second operation of a ray-tracer algorithm consists in searching for all the possible optical paths between transmitter and receiver, using the visibility tree.

[0012] The building of the visibility tree, which is the object of the first operation, has an algorithmic complexity that grows exponentially with the number of reflections requested. For this reason, as already mentioned, electronic image processing techniques are used to speed up the building and reduce the complexity of the tree.

[0013] The number of possible surfaces interacting with the rays irradiated from the source can be reduced by evaluating the angle formed between the segment that joins the source to one of the surface points under

examination and the surface point's perpendicular, according to the "back-face culling" technique, described on pages 663-664 of the book entitled "Computer Graphics: Principles and Practice" 2^{nd} edition, by J. D. Foley et al. When this angle exceeds ninety degrees the surface can be ignored in that it is physically impossible for a ray irradiated from the source to be reflected on it.

[0014] The number of surfaces can be further reduced by identifying those surfaces that are completely hidden by other objects. To do this, the article "Efficient ray-tracing technique for three-dimensional analyses of propagation in mobile communications: application to picocell and microcell scenarios," by M.F. Cattedra et al., IEEE Antennas & Propagation Magazine, vol. 40 pp. 15-28 April 1998, presents a series of geometric relations to verify whether a surface completely blacks out another surface with respect to the source. The disadvantage of this technique resides in the fact that it is necessary to define a considerable number of angular relationships that are a function of how the two surfaces are positioned in space (vertical-vertical, vertical-horizontal, vertical-slanting, etc.), and in the fact that all special cases (surfaces seen under an angle which comprises the direction 0 or 2π) must be dealt with.

[0015] To overcome this problem, F. Brunello, D. Disco and D. Gambin, in "An acceleration technique using a 3D representation for ray tracer in a urban environment", IEEE Antenna and Propagation Symposium 2000, suggest that a perspective representation centred on the source be used and implemented with well-known computer graphics processing techniques.

[0016] By representing the surfaces starting with those furthest away from the source, the closest surfaces are superimposed on the others making them disappear from the overall image. The "surviving" surfaces are the ones that will be considered by the ray tracer.

[0017] The main problem with this technique is the introduction of segment distortion into the perspective representation, if the segments are represented through the segment joining the ends: non-linear transformations are in fact used that consequently distort the surfaces.

[0018] The considerable use of trigonometric functions also makes the relative processing particularly difficult from a computation point of view.

[0019] The method for determining the values of an electromagnetic field generated by a radio base station in an urban environment, which is the subject of this invention, eliminates the aforesaid disadvantages and solves the technical problems described. It gives an accurate prediction, while the processing time required by the data processing equipment to make the calculation is much less. This is due a) to the reduction in the structure that stores the visibility relationships between the various objects under examination, i.e. the visibility tree, and b) to the simplification of the visibility test used to determine the optical paths.

[0020] The subject of this invention is a method for determining the values of an electromagnetic field generated by a radio base station in an urban environment, as described in the characterising part of claim 1.

[0021] The foregoing and other characteristics of this invention will be made clearer by the following description of a preferred form of the invention, given by way of non-limiting example, and by the annexed drawings in which:

- Fig. 1 is a schematic representation of an urban environment with a transmitter, a receiver and several buildings;
- Fig. 2 is a schematic representation of an urban environment that illustrates the construction of the transmitter images;
- Fig. 3 gives an example of a visibility tree;
- Fig. 4 illustrates a projection according to a technique called "z-buffer";
- Fig. 5 shows an example of matrixes F and Z according to the z-buffer technique;
- Fig. 6 is the flow diagram that illustrates the method of this invention.

[0022] The evaluation method proposed herein uses backward ray-tracer algorithms, which consider the rays that connect a transmission source T with a reception point R, as illustrated in Fig. 1. In this case, the direct path from T to R is not possible as building C is in the way, while the paths exploiting the reflection on the surfaces of buildings B, C and D and the diffraction on the edge of building A are possible.

[0023] The environment illustrated in Fig. 2 contains the transmission source Tx and the reception point Rx that are surrounded by four surfaces W_1, W_2, W_3 and W_4. Starting from Tx, image $I_1(W_1)$ is constructed with respect to the surface W_1, then the image $I_2(W_3)$ of image $I_1(W_1)$ with respect to surface W_3, then image I_3 (W_4) of image $I_2(W_3)$ with respect to surface W_4 and finally image $I_2(W_2)$ of image $I_2(W_3)$ with respect to surface W_2. Starting from reception point Rx, the rays are traced to the last image until they reach the point of intersection with surface W_2, thus obtaining the reflection point P_1, then from P_1 to the penultimate image $I_1(W_1)$ to obtain P_2, and so on until source Tx is reached.

[0024] Whenever a ray is traced between Rx and a reflection point or between two reflection points, it is necessary to check whether there are any obstacles in the way that may interrupt the ray, i.e. the visibility test must be carried out, which as already mentioned involves a considerable number of calculations if all the possible obstacles are to be taken into consideration.

[0025] To run this test, a visibility tree must be built. Fig. 3 shows a typical visibility tree structure between Tx and Rx. To make comprehension easier, the tree has been developed as far as the third reflection only for the paths illustrated in the Fig. 2 environment. To be more precise, images $I_1(W_n)$ are associated with the first reflection, images $I_2(W_n)$ are associated with the second

reflection and images $I_3(W_n)$ are associated with the third reflection. Each node contains the image's coordinates and a reference of the surface that generated it.

[0026] As has been stated previously, the visibility tree is rather complex; in fact the number of images to be calculated for n reflections is N • (N - 1)^5, N being the number of objects in the environment under examination. To speed up the building of this tree, the method referred to in the invention uses both the "back-face culling" technique mentioned previously, and a technique for reducing the depth of the visibility tree that exploits the z-buffer projection method.

[0027] The "back-face culling" technique is used to exclude all the objects that do not intersect the ray reflected from the surface under consideration. To check that an object does not constitute an obstacle to the ray, simply check that at least one of the following conditions exists:

- the object is not in the semi-space delimited by the plane of the reflecting surface, outside the building;
- the reflecting surface is not in the semi-space delimited by the plane of the object's surface, outside the object itself.

[0028] The technique can be applied even if the ray comes from a point source, and not from a reflecting surface. In this case, simply check that the source is not in the semi-space delimited by the plane of the object's surface.

[0029] This technique does not determine which objects in the environment constitute an obstacle to the rays, but those that do not.

[0030] The projection technique, called "z-buffer", is based on the idea of perspectively projecting the objects in the environment on the plane of the reflecting surface W_n that has generated image $I_m(W_n)$ of the source, the visibility of which is to be studied, as illustrated in Fig. 4. In this figure, object OD is projected on plane PP, on which the reflecting surface FQ lies, parallel to plane x, y of the reference system x, y, z, the origin of which is in image I.

[0031] In terms of implementation, the z-buffer technique includes two matrixes, *F* and Z, with dimensions m • n, as shown in Fig. 5.

[0032] Each cell in matrix *F* represents a geometric element of plane PP (Fig. 4) and when this element coincides with a projection element of an object in the environment, a univocal reference is stored, e.g. a progressive whole number corresponding to the object that has generated the projection.

[0033] Similarly, each cell in matrix *Z* contains coordinate *z* of the object's corresponding element, the projection of which is represented in matrix F.

[0034] To be more precise, if a polygonal object is to be represented on matrix *F*, its vertices are projected onto plane PP thus obtaining the respective cartesian coordinates *u*, *v* for each one. The number indicating the polygon is entered in cells f_{uv} of *F*; this number is also entered in all the cells that join the f_{uv} cells relating to the vertices, placed on straight segments, and in every cell contained in the perimeter that has been just traced so as to complete the representation of the polygon on the matrix.

[0035] The projections of several objects in the environment may fall on the same geometric elements of the projection plane PP, but only the z coordinates of the object nearest the projection plane must be found in the corresponding cells in the *Z* matrix. Consequently, after an object has been perspectively projected on the plane that has generated the image, the visibility of which is being studied, the z coordinate of the point of the object generating it is calculated for each geometric element in the projection. If the value is less than that already possibly in the cell as a result of a previous projection, then the new *z* value is entered, and the number indicating the object is entered in the corresponding cell of the *F* matrix.

[0036] Finally, in order to take into account all the objects seen in the image under examination, and only those objects, all the cells relating to geometric elements that do not belong to the FQ surface area that generated the projection plane PP must be eliminated from the matrixes.

[0037] In the method referred to in the invention, z-buffer projection is used to build the visibility tree. To do this it is necessary to make the hypothesis that all the objects in the urban environment can be estimated by joining flat surfaces.

[0038] If this hypothesis applies, then the buildings can be described with a set of elementary polygons (triangles, rectangles).

[0039] In this way, all the objects that can be reached by a ray reflected from an FQ polygon coincide with those in the projection plane for a system of coordinates in which:

a) The origin of the coordinated axes system coincides with image I of the source with respect to the plane on which the FQ polygon lies.

b) The projection plane Z is equal to the distance of the FQ polygon from image I.

[0040] The construction of the visibility tree is therefore reduced to three basic steps:

- Back-face culling to determine which surfaces face the reflection plane.
- Rotation and translation of the axes system to satisfy conditions a) and b).
- *z*-buffer projection.

[0041] The z-buffer technique is used in a new way to reduce the visibility tree depth by one level. By evaluating the distances in matrix Z it is possible to identify the objects nearest the reflection plane. Consequently a re-

ception point R is "visible" if its z coordinate is less than the z coordinate relating to the geometric element on which the projection of R falls.

[0042] The evaluation method that uses the above techniques is shown in the flow diagram Fig. 6.

[0043] The method starts at step 1, then goes to step 2, where the urban environment under examination is loaded by creating a list of object surfaces, each one identified by a progressive number, by the coordinates of its vertices, and by a matrix for the rotation and translation operations in the visibility calculation, etc.

[0044] The next step, number 3, is where the building of the visibility tree starts, the first operation of which, step 4, is the back-face culling of each element in the surfaces list, to initially exclude any objects that are definitely not visible.

[0045] Step 5 creates the list of source images and enters this list in the visibility tree at level 1.

[0046] Step 6 initialises the number of reflections, setting it to 1.

[0047] Step 7 checks to see whether the number of reflections is less than a maximum pre-established number of reflections, and depending on the result, the procedure may go in different directions.

[0048] In particular, if it is true that the maximum number of reflections has not been reached, answer "yes" to the check, then variable J ranging from 1 to the number of images for each level of the visibility tree, is initialised at 1, step 8.

[0049] Step 9 checks to see whether variable J is less than or equal to the number of images of the current level of the visibility tree, and depending on the result the procedure may go in different directions.

[0050] In particular, if it is not true that J is less than or equal to the number of images, answer "no" to the check, then the number of reflections is increased by one unit, step 10, and then the procedure continues to the next visibility tree level, step 11, to then return to step 7.

[0051] If, however, it is true that J is less than or equal to the number of images, answer "yes" to the check, then the operations included in the back-face culling technique are performed for each surface of the objects in the list, step 12, thus obtaining a short list containing only the surfaces that can be seen from the image.

[0052] Step 13 initialises variable K at 1, which is used at the next step, 14, to examine all the surfaces just identified, and checks to see whether the number is less than or equal to the number of surfaces, and depending on the result the procedure may go in different directions.

[0053] In particular, if it is not true that K is less than or equal to the number of surfaces, answer "no" to the check, then variable J, representing the number of images, is increased by one unit, step 15, to then return to step 9.

[0054] If, however, it is true that K is less than or equal to the number of surfaces, answer "yes" to the check, step 16 is carried out to translate the surface to make it coincide with the origin of the reference system, and step 17 is performed to rotate the same surface to make it parallel with the x, y plane.

[0055] For each translated and rotated surface, the z-buffer technique performs projection, step 18, and then the visibility test of the reception points is run using their projection on the z-buffer plane and comparison with the z coordinate, step 19.

[0056] At the next step, step 20, it is therefore possible to create the first section of the path, starting from the reception point that is shown to be visible in the previous visibility test, up to the first level reflection point.

[0057] Variable K is then increased by one unit in order to examine the next surface, step 21, and then it returns to step 14.

[0058] When step 7 shows that the number of reflections examined has reached the maximum pre-established number, answer "no" to the check, the procedure moves onto the direct visibility test between transmitter and receivers, step 22, and then the visibility test to complete the optical paths, the first section of which has already been calculated, step 23.

[0059] The method ends at step 24.

[0060] As can be seen, the z-buffer graphics acceleration technique has not only be used to build the visibility tree (step 18), but also to calculate the first part of the optical paths (step 20), eliminating the visibility comparison between the reception point and the last point of reflection. By doing so the depth of the visibility tree is reduced.

[0061] Obviously this description is given as a non-limiting example. Variants and modifications are possible, without emerging from the protection field of the claims.

Claims

1. Method for determining the values of an electromagnetic field generated by a radio base station in an urban environment, using a "backward ray-tracer" algorithm to calculate which rays connect a transmission source (T) with a reception point (R), taking into consideration that the rays can be reflected and diffracted by the surface of objects in the environment during their path, **characterised by** the fact that the "back-face culling" technique is used to exclude all the objects that fail to intersect the rays reflected from the surfaces considered, and the "z-buffer" projection technique is used to reduce by one level the structure, called the "visibility tree", of the visibility relationships between the various objects under examination.

2. Method as in claim 1, **characterised by** the fact that it includes the following steps:

   - start (step 1);

- loading of the urban environment by creating a list of object surfaces, each one identified with a progressive number, its vertex coordinates, and a matrix for rotation and translation operations (step 2);
- start of visibility tree construction (step 3);
- back-face culling for each element in the list of surfaces, in order to exclude the objects that are definitely not visible (step 4);
- creating the list of source (T) images and its entry at the first level of the visibility tree (step 5);
- initialising the number of reflections (step 6);
- checking to see whether the number of reflections is less than the maximum pre-established number of reflections (step 7);
- if the maximum number of reflections has not yet been reached, the first variable (J), which varies from 1 to the number of images for each visibility tree level, is initialised (step 8);
- checking to see if the first variable (J) is less than or equal to the number of images of the current visibility tree level (step 9);
- if the first variable (J) is not less than or equal to the number of images, the number of reflections is increased by one unit (step 10);
- moving on to the next visibility tree level (step 11), and then checking to see whether the number of reflections is less than the maximum pre-established number of reflections (step 7);
- if, however, the first variable (J) is less than or equal to the number of images, the operations envisaged in the back-face culling technique are carried out for each surface of the objects in the list (step 12), thus obtaining a list containing only the surfaces that can be seen from the image;
- initialising of the second variable (K), (step 13);
- checking to see whether the second variable (K) is less than or equal to the number of surfaces identified (step 14);
- if the second variable (K) is not less than or equal to the number of surfaces, the first variable (J) (step 15) is increased by one unit, and then the first variable (J) is checked again to see whether it is less than or equal to the number of the images of the current visibility tree level (step 9);
- if the second variable (K) is less than or equal to the number of surfaces, the surface is translated in order to make the image coincide with the origin of a reference system (**x**, y, z) (step 16);
- rotating of the same surface in order to make it parallel to plane (**x**, y) of said reference system (step 17);
- for each translated and rotated surface, projection is made according to the z-buffer technique, (step 18);
- visibility test of the reception points (R) by projecting them onto a z-buffer plane (PP) and comparing the (z) coordinate (step 19);
- creating the first section of the ray's path, starting from the reception point (R) that is "visible" in the previous test, to the first level reflection point (step 20);
- increasing of the second variable (K) by one unit so as to examine the next surface (step 21), and then checking again to see if the second variable is less than or equal to the number of surfaces identified (step 14);
- if the number of reflections examined has reached the maximum pre-established number (step 7), the direct visibility test between the source (T) and the receiver points (R) is carried out (step 22);
- running of the visibility test to complete the optical paths, the first section of which has already been calculated (step 23);
- end (step 24).

3. Method as in claim 1 or 2, **characterised by** the fact that, in order to carry out the visibility test, the visibility tree is built between source (T) and reception point (R), in which the source is connected to an initial set of nodes representing the images ($I_1(W_n)$) associated with the first reflection, each node of the first order being connected to several nodes of the second order representing the images ($I_2(W_n)$) of the second reflection and so on, each node containing the coordinates of the image and a reference of the surface that generated it.

4. Method as in any of claims 1 to 3, **characterised by** the fact that in order to project according to the z-buffer technique, objects in the environment (OD) are projected perspectively onto plane (PP) of the reflecting surface (FQ) that has generated the image ($I_m(W_n)$) of the source (T), the visibility of which is to be tested, said plane (PP) being parallel to the plane (x, y) of the (x, y, z) reference system, the origin of which is in the image (I).

5. Method as in any of claims 1 to 4, **characterised by** the fact that a first matrix (*F*) and a second matrix (*Z*) of dimensions m • n are built according to the z-buffer technique, each cell of the first matrix (F), representing a geometric element of the plane (PP) of the reflecting surface (FQ), containing a univocal reference to the object that generated the projection, when this element coincides with an element of the projection of an object in the environment.

6. Method as in claim 5, **characterised by** the fact that each cell of the second matrix (*Z*) contains the coordinate (*z*) of the corresponding element of the object, the projection of which is represented in the

first matrix (*F*).

7. Method as in claim 6, **characterised by** the fact that, if the projections (OP) of more than one environment object (OD) fall on the same geometric elements of the projection plane (PP), only the minor (*z*) coordinates, which correspond to those of the object nearest the projection plane (PP), are entered in the second matrix (*Z*) cells, and the univocal object reference is entered in the corresponding cell in the first matrix (*F*).

8. Method as in claim 4 or any of claims 5 to 8 if referred to claim 4, **characterised by** the fact that all the cells relating to the geometric elements that do not belong to the surface area (FQ) that generated the projection plane (PP) are eliminated from the matrixes (*F*, *Z*).

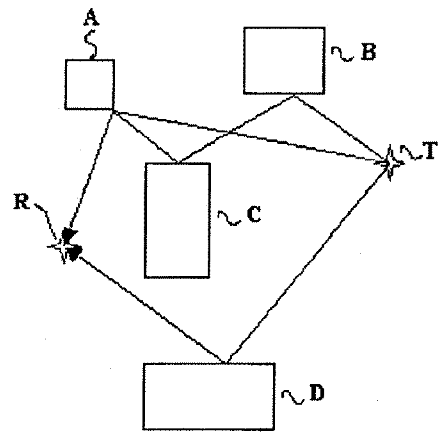


Fig. 1

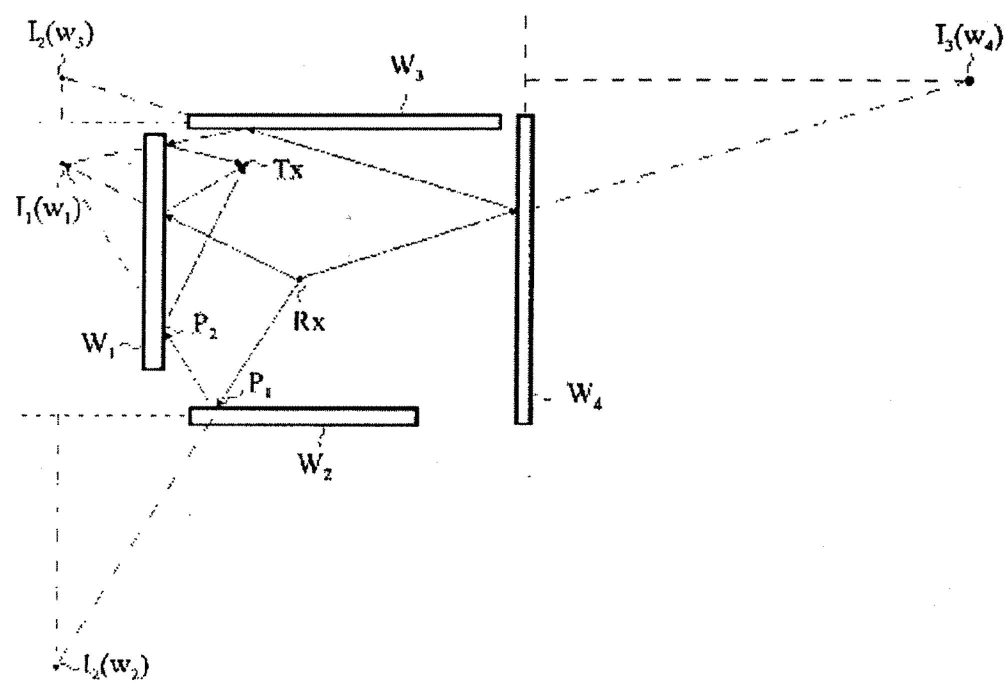
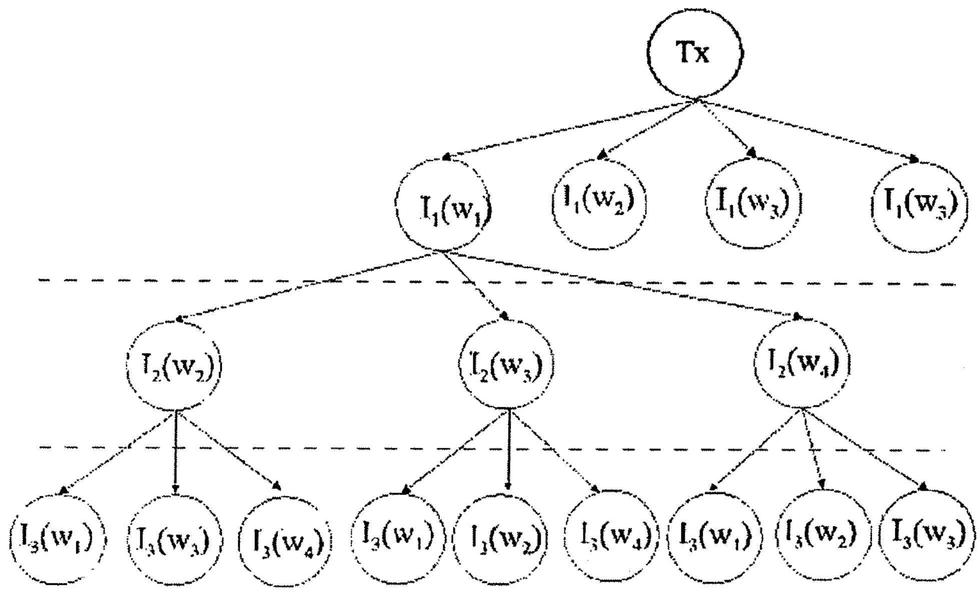


Fig. 2


Tx
$I_1(w_1)$
$I_1(w_2)$
$I_1(w_3)$
$I_1(w_3)$
$I_2(w_2)$
$I_2(w_3)$
$I_2(w_4)$
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$I_3(w_3)$

Fig. 3

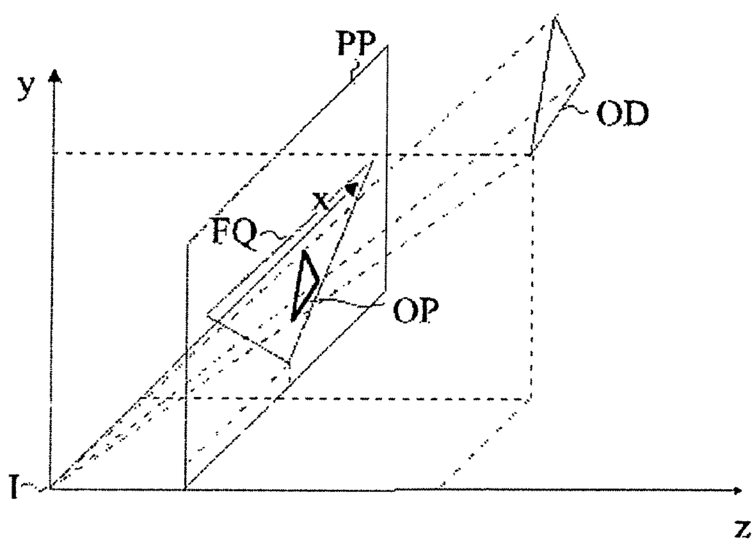
PP
y
OD
x
FQ
OP
I
z

Fig. 4

$$F = \begin{array}{|c|c|c|c|}\hline f_{1\,1} & f_{1\,2} & \cdots & f_{1\,n} \\ \hline f_{2\,1} & f_{2\,2} & \cdots & f_{2\,n} \\ \hline \vdots & \vdots & \ddots & \vdots \\ \hline f_{m\,1} & f_{m\,2} & \cdots & f_{m\,n} \\ \hline \end{array}$$

$$Z = \begin{array}{|c|c|c|c|}\hline z_{1\,1} & z_{1\,2} & \cdots & z_{1\,n} \\ \hline z_{2\,1} & z_{2\,2} & \cdots & z_{2\,n} \\ \hline \vdots & \vdots & \ddots & \vdots \\ \hline z_{m\,1} & z_{m\,2} & \cdots & z_{m\,n} \\ \hline \end{array}$$

Fig. 5

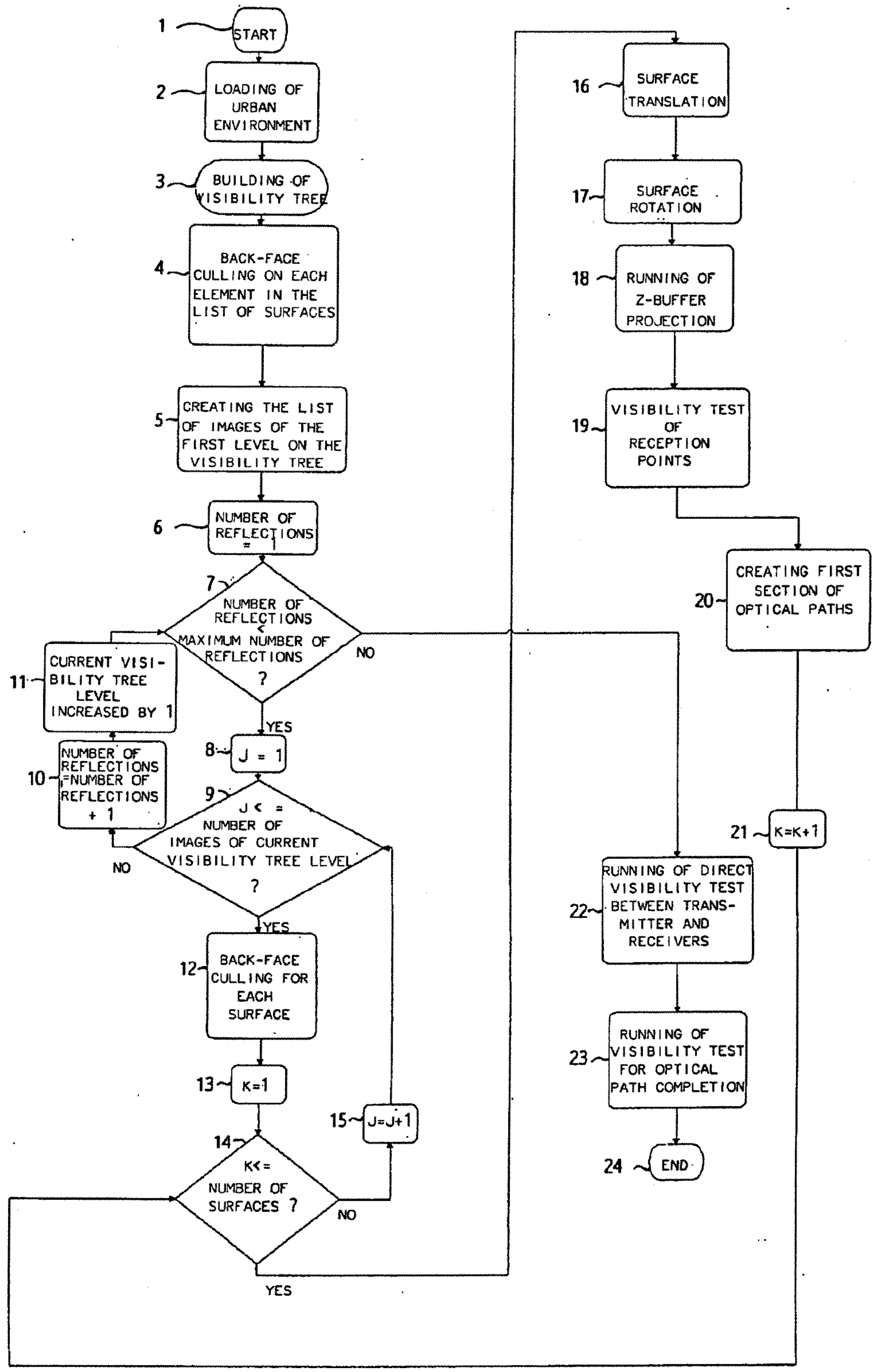
1
START
2
LOADING OF URBAN ENVIRONMENT
3
BUILDING OF VISIBILITY TREE
4
BACK-FACE CULLING ON EACH ELEMENT IN THE LIST OF SURFACES
5
CREATING THE LIST OF IMAGES OF THE FIRST LEVEL ON THE VISIBILITY TREE
6
NUMBER OF REFLECTIONS = 1
7
NUMBER OF REFLECTIONS < MAXIMUM NUMBER OF REFLECTIONS ?
NO
YES
8
J = 1
9
J < = NUMBER OF IMAGES OF CURRENT VISIBILITY TREE LEVEL ?
NO
YES
10
NUMBER OF REFLECTIONS =NUMBER OF REFLECTIONS + 1
11
CURRENT VISIBILITY TREE LEVEL INCREASED BY 1
12
BACK-FACE CULLING FOR EACH SURFACE
13
K=1
14
K<= NUMBER OF SURFACES ?
NO
YES
15
J=J+1
16
SURFACE TRANSLATION
17
SURFACE ROTATION
18
RUNNING OF Z-BUFFER PROJECTION
19
VISIBILITY TEST OF RECEPTION POINTS
20
CREATING FIRST SECTION OF OPTICAL PATHS
21
K=K+1
22
RUNNING OF DIRECT VISIBILITY TEST BETWEEN TRANSMITTER AND RECEIVERS
23
RUNNING OF VISIBILITY TEST FOR OPTICAL PATH COMPLETION
24
END

Fig.6

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 02 02 0048

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	WO 96 31099 A (MOTOROLA INC) 3 October 1996 (1996-10-03) * claims 1-10 * ---		H04Q7/36
A	US 5 949 988 A (RAUKUMAR AJAY ET AL) 7 September 1999 (1999-09-07) * column 3, line 19 - column 4, line 41 * ---		
A	AGELET F A ET AL: "EFFICIENT RAY-TRACING ACCELERATION TECHNIQUES FOR RADIO PROPAGATION MODELING" IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, IEEE INC. NEW YORK, US, vol. 49, no. 6, November 2000 (2000-11), pages 2089-2104, XP001048946 ISSN: 0018-9545 * page 2089, right-hand column, line 6 - line 17 * * page 2089, right-hand column, line 42 - page 2092, right-hand column, line 9 * ---		
A	SÂNCHEZ M G ET AL: "Exhaustive ray tracing algorithm for microcellular propagation prediction models" ELECTRONICS LETTERS, IEE STEVENAGE, GB, vol. 32, no. 7, 28 March 1996 (1996-03-28), pages 624-625, XP006004965 ISSN: 0013-5194 * the whole document * -----		TECHNICAL FIELDS SEARCHED (Int.Cl.7) H04Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 January 2003	Coppieters, S

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 02 02 0048

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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21-01-2003

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US 5949988	A	07-09-1999	NONE		

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82